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Leveraging Reinforcement Learning, Genetic Algorithms and Transformers for background determination in particle physics

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Experimental studies of beauty hadron decays face significant challenges due to a wide range of backgrounds arising from the numerous possible decay channels with similar final states. For a particular signal decay, the process for ascertaining the most relevant background processes necessitates a detailed analysis of final state particles, potential misidentifications, and kinematic overlaps, which, due to computational limitations, is restricted to the simulation of only the most relevant backgrounds. Moreover, this process typically relies on the physicist's intuition and expertise, as no systematic method exists.

This work has two primary goals. First, from a particle physics perspective, we present a novel approach that utilises Reinforcement Learning (RL) to overcome the aforementioned challenges by systematically determining the critical backgrounds affecting beauty hadron decay measurements. While beauty hadron physics serves as the case study in this work, the proposed strategy is broadly adaptable to other types of particle physics measurements. Second, from a Machine Learning perspective, we introduce a novel algorithm which exploits the synergy between RL and Genetic Algorithms (GAs) for environments with highly sparse rewards and a large trajectory space. This strategy leverages GAs to efficiently explore the trajectory space and identify successful trajectories, which are used to guide the RL agent's training. Our method also incorporates a transformer architecture for the RL agent to process token sequences that represent particle decays.

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